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SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE[1]

Boss[2] describes the dikes associated with the ore deposits of the Gogebic iron range. They are dioritic and more or less altered; they are approximately at right angles with the dip of the formation they cut, and the greater number of them have an average easterly dip of 15° to 18°—sometimes they are folded in such a manner as to form long synclinal basins with eastward pitch. In a majority of cases mining exploitation has shown a succession of dikes, one below the other, and ferruginous quartzite of varying thickness immediately underlying each dike and forming the cap of the succeeding deposit of ore.

Comment.—The dikes have been shown by Irving and Van Hise[3] to be diabase, rather than diorite. With this exception, the above observations are in accord with and confirm those of Irving and Van Hise in this area, and except in a few details nothing new is presented. For a comprehensive discussion of the position of the dikes and their relations to the ore bodies the reader is referred to Monograph XIX of the United States Geological Survey.

Wadsworth[4] describes the origin and mode of occurrence of the Lake Superior copper deposits, and the age of the copper-bearing series. A reëxamination of the Douglass Houghton and Hungarian River areas shows that the Eastern Sandstone passes under the lavas with increasing dip, and that the junction is not a fault junction, but that of a lava flow upon an underlying soft sand and mud. It is held that the Eastern Sandstone is of Potsdam age, and underlies the copper-bearing series, the first lava of that series having flowed out upon the sandstone. The basaltic rocks forming the Bohemian Mountains present phenomena which indicate their eruption subsequent to the formation of the main deposits of the region, although the question is as yet open. Subsequent to the deposition of the Keweenawan a fissure was formed near the contact of the Eastern Sandstone and the lavas, along which normal faulting occurred, the copper-bearing series forming the overhanging side of the fault. As to the nature of the displacement, however, more evidence is needed. The copper occurs in fissure veins, in melaphyres, and in conglomerates.

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[1] Continued from p. 854, Vol. VI, JOUR. GEOL.

[2] Some dike features of the Gogebic iron range, by C. M. BOSS, Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 556–563.

[3] The Penokee-Gogebic iron-bearing series of Michigan and Wisconsin, by R. D. IRVING and C. R. VAN HISE: Mon. U. S. Geol. Surv., No. XIX, 1892.

[4] The origin and mode of occurrence of the Lake Superior copper deposits, by M. E. WADSWORTH: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 669–696.

Comments.—That the Keweenawan was deposited on the Eastern Sandstone was held by Wadsworth before the publication of Irving's[1] report on the copper-bearing series in 1883. In his report Irving presented evidence to show that this could not be the case, but that the sandstone is post Keweenawan; and later, in 1885, Irving and Chamberlin[2] in a more comprehensive discussion of the relations of the Keweenawan to the Eastern Sandstone, proved still more clearly the post-Keweenawan age of the Eastern Sandstone. Subsequently, in 1893, Wadsworth took the view that the Keweenawan formed the lower part of the Potsdam, and explained the phenomena on the theory that the Eastern Sandstone, instead of being one sandstone, may contain two or three sandstones of different ages. In the article above reviewed Wadsworth has gone back to his earlier view. However, he has not yet met the arguments so clearly stated by Irving and later and more comprehensively, by Irving and Chamberlin.

Berkey[3] describes and maps the geology of the St. Croix dalles of Wisconsin and Minnesota. Keweenawan eruptives are exposed at numerous localities, and particularly along the river, where, by their erosion, they have formed the dalles of the St. Croix River. The dip is about 15° to the south, which would give a thickness to the rocks in sight of 4000 feet. At several localities the Basal Sandstone unconformably overlies the Keweenawan eruptives with visible contacts, the

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[1] The copper-bearing rocks of Lake Superior, by R. D. IRVING: Mon. U. S. Geol. Surv., No. V, 1883.

[2] Observations on the junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. IRVING and T. C. CHAMBERLIN: Bull. U S. Geol. Surv., No. XXIII, 1885.

[3] Geology of the St. Croix Dalles, by C. P. BERKEY: Am. Geol., Vol. XX, 1897, pp. 348–383, and Vol. XXI, 1898, pp. 139–155, 270–294.

Basal Sandstone including the sandstone and shale series between the Keweenawan and the St. Lawrence shales.

Winchell[1] discusses the significance of the fragmental eruptive débris at Taylor's Falls, Minn. This has heretofore been regarded as a conglomerate resting unconformably upon the Keweenawan. As a result of recent field work by Mr. C. P. Berkey, it is believed that this conglomerate may be separated into two conglomerates, an upper one at the base of the upper division of the Cambrian, and a lower one at the base of the lower division. The latter would come within the Keweenawan, as this term is used by Irving and other writers, and would separate this series into two parts.[2] The later conglomerate rests directly upon the earlier one, leading to the previous confusion of the true relations. Similar conglomerates found in the Keweenawan at several points between Duluth and Grand Portage have led to the conclusion that the Keweenawan may be divided into two great series, separated by conglomerate and quartzite which reach a thickness of several hundred feet. The lower series has been included in the Norian, and the upper series comprising the sedimentaries and the eruptives above them, has been called Keweenawan, the Keweenawan forming the lower division of the Cambrian.

Comments.—While the conglomerate within the Keweenawan at this locality has not before been noted, the occurrence of many conglomerates at other localities in the middle and upper part of the Keweenawan has been mapped and described by the Michigan and United States geologists, as a glance at Marvin's Eagle River section[3] and Irving's general report[4] on the Keweenawan will indicate. Instead of one conglomerate, there are a dozen conglomerates at different horizons. However, these conglomerates are composed almost without exception of local material, derived wholly from contemporaneous lava flows, and are held to mark very insignificant breaks in the series. As seen from Winchell's description, the Taylor's Falls conglomerate belongs to this class. The United States geologists, recognizing the local character of the conglomerates, have considered the series including them as a unit, and, regarding the hiatus at the top of the series as much more profound than that at the bottom, have included the series in the Algonkian, rather than in the Cambrian. Winchell and many of the Canadian geologists, on the other hand, have recognized but one conglomerate within the Keweenawan, and, giving this undue significance, have extended the Cambrian downward to this conglomerate, thereby including in the Cambrian the profound unconformity separating the Keweenawan series and the fossil-bearing Cambrian. If Winchell's reasoning be carried to its logical conclusion, wherever a conglomerate is found within the Keweenawan, the series must there be divided, and in place of one series, we shall have many series, a division which cannot be considered reasonable. It appears, therefore that Winchell's division of the Keweenawan into two series, on the basis of local conglomerates such as the one described from Taylor's Falls, is purely arbitrary, and furthermore, by referring his upper division to the Cambrian, the profound unconformity known to exist between the true Cambrian and the Keweenawan is practically ignored.

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[1] The significance of the fragmental eruptive débris at Taylor's Falls, Minn., by N. H. WINCHELL: Am. Geol., Vol. XXII, 1898, pp. 72–78.

[2] In a recent paper, above summarized, MR. BERKEY (Am. Geol., Vol. XX, p. 381) takes the view that the lower conglomerate is a flow breccia of the igneous rocks.

[3] Geology of Michigan, 1873, Vol. I, Part II, Copper-bearing rocks, pp. 117–140.

[4] Copper-bearing rocks of Lake Superior, Mon. V, U. S. Geol. Surv., 1883.

Winchell[1] discusses the Archean greenstones of Minnesota, which he considers the oldest known rocks, representing the original crust of the earth. The greenstones are divisible into two parts, one igneous and the other clastic, the latter succeeding the former with a confused, and apparently sometimes conformable superposition, somewhat as surface eruptive rocks might be superposed, in the presence of oceanic action, upon a massive of the same nature at the same place. The clastic portions of the greenstones vary to more siliceous rocks, constituting great thicknesses of graywackes, phyllites, and conglomerates, and as such have been converted by widespread metamorphism into mica-schists and gneisses.

As the Laurentian gneisses and granites cut the schists and sedimentary gneisses they are also younger than the bottom greenstones.

The metamorphic schists and gneisses seem to be representative of the sedimentary portion of the Lower Laurentian of Canada, while the igneous granite and gneisses are as plainly a general parallel of the igneous portion of that series. It follows, therefore, that the Canadian Laurentian is, as a whole, of later date than the greenstones, if the succession is the same as in the Northwest, and that the greenstones should be considered the bottom rock of the geological scale.

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[1] The oldest known rock, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci. Vol. LXVII, 1898, pp. 302, 303 (Abstract).

Winchell[1] attempts to explain the origin of the Archean igneous rocks. From field evidence and petrographic discriminations and associations, it is believed that the alkaline magma from which the igneous rocks were derived is the result of aqueo-igneous fusion of the fragmentals of the Archean itself; that when deeply buried, under heat and pressure, the Archean clastics were rendered plastic, penetrating openings in the adjacent and superjacent strata; and that when the plastic mass was not moved from its place it was simply recrystallized *in situ*.

The clastic rocks must have been derived from the basal greenstone, which is considered representative of the original crust of the earth. The presence in such clastics of sufficient potassa and silica to yield upon fusion the granitic magmas is explained on the hypothesis that they must have come from the waters depositing the fragmentals, and primarily from the atmosphere, in its condition normal to the Archean age, just following the congealing of the first crust.

While numerous instances of such transition from clastic to igneous rock have been noted in Minnesota, there has been a careful study of but one. That was the case of the granite and porphyry which intrude the clastics at Kekequabic Lake.

Winchell[2] presents some additional points on the geology of northeastern Minnesota.

The Laurentian includes, in Minnesota, an acid crystalline schist of sedimentary origin, and a massive igneous rock, although the igneous rock is younger than the crystalline schist portion, and should have a different designation. The conclusions reached are that: (1) the sedimentary Laurentian is a crystalline condition of sedimentary strata, which are conformably a portion of the sedimentary schists; (2) the igneous Laurentian is the result of a more intense metamorphism, carried even to fusion of some strata. These conclusions result particularly from the study of a section from Tower northward, through Vermilion

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[1] The origin of the Archean igneous rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299–310.

[2] Some new features in the geology of northeastern Minnesota, by N. H. WINCHELL: Am. Geol., Vol. XX, 1897, pp. 41–51.

Lake, and of an area on the west side of Outlet Bay, in the corners of sections 13, 14, 21, and 32, T. 63 N., R., 17 W., and along the shore for one half mile westward.

It is evident that the Stuntz conglomerate on the south shore of Vermilion Lake is a true water-deposited conglomerate, of the same formation as the slates and graywackes of the district, the conglomerate grading into the quartzite and graywacke, and this into argillaceous slate. Furthermore, as supposed by Van Hise, the conglomerate lies unconformably on the iron-bearing formation, and contains very numerous fragments of jaspilite. The position of this unconformity, whether at the base of the Taconic or lower is not ascertained.

The nature and position of the conglomerate in the valley of the Puckwunge, a small stream entering the Pigeon River north of Grand Portage, is discussed. This conglomerate is overlain by igneous rocks, resembling the traps of the Keweenawan. The subjacent formation cannot be certainly determined, but in the same locality, at a lower level, is a slate rock, called the Puckwunge slate, which was followed for some distance north and east, and which is probably an upper member of the Animikie, not before individualized. The conglomerate contains quartzite pebbles, which are referable to the quartzites of the Animikie, farther north. It may be inferred that this is the basal conglomerate of the Keweenawan, which has been identified up to Grand Portage island, and at intervals along the Lake Superior coast, from Baptism River to near Beaver Bay.

Winchell[1] discusses some resemblances between the Archean of Minnesota and of Finland. The succession in northeastern Minnesota, as made out largely from field work done in 1897, is as follows, in descending order.

1. *Granitic intrusion*, cutting and metamorphosing the earlier schists and fragmentals. This rock is seen about Snowbank Lake and Moose Lake, about the western confine of Disappointment Lake, and at Kekequabic lake.

2. *Upper Keewatin.*—This consists of conglomerates (at Stuntz Island and at Saganaga and Ogishkie Muncie lakes), sericitic schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids. The mica-schists, embracing many conspicuous bowlder-

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[1] Some resemblances between the Archean of Minnesota and of Finland, by N. H. WINCHELL: Am Geol., Vol. XXI, 1898, pp. 222–229.

like forms on the weathered surfaces, are to be seen about Moose Lake, and southeast to Snowbank Lake, about Disappointment Lake, Kekequabic Lake, and eastward to Zeta Lake.

3. *Granitic intrusion,* chiefly represented by the granite of Saganaga Lake, where the Upper Keewatin lies unconformably upon it. It is also seen a little west of Ely and on the Kawishiwi River. At West Seagull Lake this granite cuts older greenstones and green schists.

4. *Lower Keewatin or Kawishiwin.*—This is mainly a greenstone formation, both massive and fragmental, and constitutes the oldest formation in the state. When stratified it consists of basic tuffs, agglomerates, and green stratified schists and greenwackes. It contains the banded jaspylites and iron ores at Vermilion Lake. Where cut by granite and porphyry (1), these rocks are converted to mica-schist and banded gneiss.

Unconformably above all these is the Animikie formation, of Taconic age, the base of the Paleozoic.

Nos. (1), (2) and (3), above, are paralleled in Finland by similar rocks in similar order, as described by Sederholm. Rocks corresponding to No. (4), the Lower Keewatin, seem to be wanting, or are seen only as inclusions in the next younger granite.

It is probable that the divisions above detailed for Minnesota and Finland are wholly embraced in the lower division of the Canadian Laurentian, *i. e.*, in the Ottawa gneiss, and that they have not yet been noted in Canada. The fundamental gneiss of Canada is, therefore, not the bottom of the geological series, but is largely a sedimentary series, derived from an older series, this older series being in part at least a greenstone, as indicated by the stratigraphic succession in Minnesota.

Comments.— In the above papers Winchell has modified his ideas from time to time with reference to the general succession of the pre-Cambrian rocks of northeastern Minnesota, and it may be well briefly to summarize what appear to be his latest conclusions. The succession from the base upward is as follows: (1) greenstone, both massive and fragmental, called the Lower Keewatin ; (2) cutting this is a massive granite, typically developed at Saganaga Lake ; (3) unconformably above the Lower Keewatin is a series of sedimentary rocks, consisting of conglomerates, sericite-schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids, called the Upper Keewatin ; (4) granite cutting and metamorphosing all the preceding.

The correlation of the Minnesota series with the Ottawa gneiss and with the Finland series must be considered a pure conjecture. The Minnesota succession is not agreed upon; these widely separated regions have not been connected by structural work, and of course in the case of Finland never can be; and lastly, fossil evidence is lacking. Any correlation of the ancient crystalline rocks without the basis of connecting structural work or fossil evidence, must be considered as little more than a guess, having no foundation in inductive knowledge.

The massive igneous rocks of the Laurentian, mostly granites, which intrude the sedimentary rocks, are believed by Winchell to be due to the aqueo-igneous fusion of the lower portion of the sedimentary rocks, and the intrusion of the magma thus formed into the overlying sediments. The argument adduced in favor of this origin is based almost entirely upon an occurrence cited at Kekequabic Lake of a transition from igneous rocks to the clastic rocks there found. In 1891 and 1892 Grant[1] studied this area, and found no evidence of a transition from the semicrystalline and crystalline schists into granite. On the contrary, abundant evidence was found of the eruptive nature of the granitic rocks in the surrounding sedimentaries. The same area was closely studied by a party of the U. S. Geol. Survey during 1898, and the same conclusion was reached. The principal support of Winchell's theory is thus taken away, and it stands as an unproved hypothesis.

Grant[2] describes and maps the geology of Kekequabic Lake in northeastern Minnesota. By far the larger proportion of the rocks represented are clastics, which are divided for convenience into four groups. The first and most extensive group is the slate formation, consisting largely of argillites, with smaller amounts of fine and coarse graywackes and grits, the coarser phases becoming distinctly conglomeratic in places. The second group consists of coarse conglomeratic rocks, which are a part of the Ogishke conglomerate. The third group is made up of certain fissile green schists, which are believed to be water deposited, and probably originally formed from fine volcanic ash. The fourth group consists of volcanic fragmental material, in part deposited in water. All of these clastic rocks now stand in nearly vertical positions, with a strike a little north of east.

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[1] Twentieth Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., 1893, pp. 69–82; and Twenty-first Ann. Rept., *ibid.*, pp. 50–54.

[2] The geology of Kekequabic Lake in northeastern Minnesota, with special reference to an augite soda granite, by U. S. Grant: A thesis accepted for the degree of Ph.D in The Johns Hopkins University, 1893. Published in Twenty-first Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., for 1892, pp. 5–58, 1893. With geol. map and plates.

Sharply marked off from the clastic rocks are four types of igneous rocks, hornblende-porphyrite, granite, diabase, and gabbro. The granite is divisible into two types, ordinary granite, and granite-porphyry, in both of which the ferro-magnesian constituent is almost exclusively pyroxene and the predominating feldspar anorthoclase. The origin of the granite is truly eruptive; having broken through the surrounding clastics; the rock is not formed, as held by N. H. and A. Winchell, from the recrystallization in situ of the sedimentaries of the region.

The slate formation, the green schist, and the volcanic tuff belong to the Keewatin, the Minnesota equivalent of the Lower Huronian. The conglomerate contains pebbles, many of which are similar to some of the Keewatin rocks, and it seems to belong to a newer series, although as yet no unconformity between the conglomerate and other rocks has been discovered. Following Lawson, it is believed that the conglomerate is a part of the Keewatin, probably separated from the lower part of that series by an unconformity, and that it is much older than the Animikie. However, the question whether the clastics belong to one or two series is as yet open.

The porphyrite and the granite are of Keewatin age. The porphyrite is regarded as contemporaneous with the deposition of volcanic tuff and green schist, and the granite is believed to date from the folding of the Keewatin. The age of the diabase dikes is not known; they are perhaps contemporaneous with the great diabase intrusions in the Animikie. The gabbro is of early Keweenawan age.

Grant[1] sketches the geology of the eastern end of the Mesabi iron range in Minnesota, including T. 64 N., Rs. 3 and 4 W., and parts of Rs. 2 and 5 W., with some adjacent portions of Ontario. The rocks can be separated into three divisions. The chief one of these is the Animikie series, containing the iron bearing rocks of the Mesabi range. Older than the Animikie is a series of granites, greenstones both massive and schistose, conglomerates, slates, and other clastic rocks, called the pre-Animikie. Younger than the Animikie are some diabase sills and the great gabbro mass of northeastern Minnesota.

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[1] Sketch of the geology of the eastern end of the Mesabi iron range in Minnesota, by U. S. GRANT: Engineers' Year Book, Univ. of Minn., 1898, pp. 49–62. With sketch map.

Of the pre-Animikie rocks, the greenstones and clastic rocks have been called Keewatin. As the greenstones are usually associated with the Mesabi iron-bearing rocks, these alone of the Keewatin rocks are described. They lie to the north of the iron-bearing rocks in T. 65 N., R. 5 W., and extend eastward to the center of T. 65 N., R. 4 W., where they disappear under the Animikie strata. In general, the greenstones are at present diorites; originally some were certainly diabases, others were of the nature of andesites, and a large part were diorites, or possibly gabbros. At places, especially along the east side of Sec. 27, T. 65 N., R. 5 W., the greenstones contain angular and subangular fragments of rock almost like themselves, and some may be regarded as composed of fragmental volcanic rocks. Associated with the greenstones, especially in Secs. 22, 23, and 24, T. 65 N., R. 5 W., are small masses of more acid rocks, quartz porphyries and quartzless porphyries, which are probably younger than the greenstones.

The pre-Animikie granite has its typical development on the shores of Saganaga Lake. In a number of places it may be seen in intrusive relations with the greenstone. A quarter of a mile south of the N. E. corner of Sec. 23, T. 65 N., R. 5 W., many granite dikes cutting the greenstone are seen, and on the south shore of West Seagull Lake granite dikes of the same nature as the immediately adjacent main mass of Saganaga granite are seen cutting the greenstone. Both granite and greenstone are cut by another series of finer grained, more acid granite dikes.

The Animikie rocks rest unconformably upon the pre-Animikie rocks, and usually on the southern slope of the Giant's Range, which is composed essentially of granite. The strike is approximately E. N. E., and the dip in general about 10° E. of S. The thickness varies from nothing to 4000 feet. The Animikie is separable into four conformable divisions: (1) the lower or quartzite member, called the Pewabic quartzite; (2) the iron-bearing or taconyte member; (3) the black slate member; (4) the graywacke-slate member.

(1) The quartzite member is well developed in Itasca county, but disappears before reaching the eastern side of St. Louis county.

(2) The rocks of the iron-bearing member are similar to those in St. Louis county on the western end of the range, described by Spurr.[1] They differ, however, in two features. They are more completely

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[1] Geol. and Nat. Hist. Surv. of Minn., Bull. X, 1894.

crystalline, and the iron is magnetite instead of hematite. The rocks consist chiefly of jaspers, amphibole (grünerite) schists, greenish siliceous slates, cherts, cherty carbonates, and magnetite slates. It is believed that these rocks were originally glauconitic green-sands; that the ore has been derived from the iron in the glauconite, and that the ore bodies result from concentration and replacement. In this part of the Mesabi range no ore bodies have yet been found which are at the same time both rich enough and large enough for profitable mining, although vast quantities of magnetite ore occur at or near the surface.

The dip of this formation varies from an average of 45° to 50° on the west to less than 15° on the east, and the thickness varies from 650 feet or less on the west to 900 feet on the east.

(3) The black slate is essentially a fine-grained, black, more or less siliceous, apparently carbonaceous slate.

(4) The graywacke-slate member is composed of black to gray slates and fine graywackes, with some flinty slates; the upper part shows coarser detrital material, and the highest beds seen are fine-grained quartzites and quartz-slates. This member is well exposed on the south shore of Loon Lake.

Associated with all of the strata of the Animikie are diabase sills, and bounding the Animikie rocks on the south is the great gabbro mass. These are igneous rocks of later date than the Animikie. Near the contact with the gabbro the Animikie rocks show marked metamorphism, and usually complete recrystallization. The gabbro varies from a nearly pure plagioclase rock to titaniferous magnetite.

The pre-Animikie rocks here described, according to the nomenclature used by the United States Geological Survey, belong to the Lower Huronian series of the Algonkian system, and probably also in part to the older Archean or Basement Complex; the Animikie is regarded as the equivalent of the Upper Huronian series of the Algonkian, and the gabbro as the lower part of the Keweenawan series of the Algonkian.

Winchell, Alexander,[1] gives a detailed petrographical description of the Koochiching granite occurring on the north boundary of Minnesota, about two miles west of Rainy Lake. The rock is a biotite-hornblende granite of eruptive origin, and is assigned to the Laurentian.

[1] The Koochiching Granite, by ALEXANDER WINCHELL: Am. Geol., Vol. XX, 1897, pp. 293–299.

Coleman makes notes on the petrology of Ontario, including the Port Coldwell, Missanabie, and Wahnapitae areas.[1]

Coleman makes a third report on the gold region of western Ontario.[2]

The districts visited and here reported upon are the Upper Seine district, the Shoal Lake district, the Manitou district, the country crossed between Manitou Lake and the Lake of the Woods, the Lake of the Woods district, the West Shoal Lake district, the neighborhood of Rat Portage, and the vicinity of Fort William on Lake Superior. As in previous reports, the general geology worked out by Lawson for the Lake of the Woods and Rainy Lake districts is accepted, and the general principles applied to other districts of the region visited.

In previous years it has been held that gold was to be looked for only in the Huronian. During the past three years, however, it has been found that some of the most promising gold deposits occur in the granite or gneiss. It has also been found that the best veins, or other ore deposits, occur at or near the contact of the Laurentian eruptive rocks and the Huronian.

In the Ontario region the gold deposits occur in the following ways. (1) True fissure veins, commonly found in the areas of massive eruptive granite. (2) Lenticular or bedded veins, confined to the schistose rocks. These are intercalated between the schists and run parallel with their strike, and are not so continuous as the fissure veins. (3) Contact deposits, between the Huronian and Laurentian. These are rare in this district. (4) Fahlbands of schists, impregnated with pyrites and other sulphides. (5) In quartz, associated with dikes of porphyry or felsite, near the contact of the Huronian and Laurentian rocks, penetrating the schists, and sometimes the granite itself. (6) In an eruptive mass, in but one locality. (7) Placer deposits.

Coleman[3] gives an interesting general account of the clastic Huronian rocks of Western Ontario, in the region extending from the Lake of the Woods in the west to Lac des Mille Lacs on the east, a distance of 200 miles, with a width north of Rainy Lake of 120 miles. The Huronian, including the Keewatin and Couchiching rocks, is in general an immense series of water-worn sediments, in the upper part mixed with eruptives, perhaps largely later injections, but partly pyroclastic. The Keewatin is largely of eruptive origin, though it contains important sedimentary members; the Couchiching is entirely sedimentary.

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[1] Notes on the petrology of Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1898, pp. 145–150.

[2] Third report on the west Ontario gold region, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1897, pp. 71–124.

[3] Clastic Huronian rocks of Western Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 151–160. Published also in Bull. G. S. A. Vol. IX, 1898, pp. 223–238.

The Keewatin, and in the southern part of the region the underlying Couchiching, form sharp synclines, curving as wide meshes around the areas of Laurentian, which vary from less than a mile to fifty miles in diameter.

Diabase and porphyry eruptives form an important part of the Keewatin. These are in large part surface flows, represented by ash rocks, agglomerates, etc., but many of them are probably laccolitic sills. The water-formed clastics of the Keewatin, include limestones, slates, quartzites, grits, graywackes, breccias, and pebble and bowlder conglomerates. The limestones are of limited extent, being found in any thickness only at Steep Rock Lake. The slate on analysis yields 7.44 per cent. of carbon, pointing perhaps to the presence of life. The conglomerates are in places schistose. Near Shoal Lake the most common pebbles are quartz-porphyry and porphyrite, felsite, and green schists indistinguishable from the adjoining Keewatin schists; black and red quartzite, white pulverulent sandstone, vein quartz, and anorthosite. No gneiss or granite pebbles have been found. Most of these pebbles are easily matched by Keewatin rocks, sometimes, however, many miles distant; a few are evidently Couchiching; and none are Laurentian.

The break represented by this conglomerate comes high up in the Keewatin, instead of at its base, just above the Couchiching, as held by Lawson. Striking evidence that the break is not at the base of the Keewatin is found at Shoal Lake, where a few bowlders of the coarse-grained anorthosite found in the schist-conglomerate are exactly like portions of a boss of anorthosite two miles away. As this anorthosite area contains masses and strips of characteristic Keewatin schist, swept off during its eruption, it is evident that an immense lapse of time separates the conglomerate and the underlying Keewatin. It is probable that the conglomerates represent an important interval of erosion, perhaps equivalent to the one shown by Van Hise and others between the Upper and Lower Huronian in the states to the south.

The Couchiching rocks are all formed of clay sand, more or less metamorphosed; in general they are biotite-schists or gneisses, the quartz showing a clastic origin. The Couchiching passes up by transition into the Keewatin, and there is no reason why the two together should not be classed as Huronian.

Following Lawson's estimate, the Keewatin and Couchiching series together sum up 50,000 feet in thickness.

The term Laurentian is employed, as Lawson and other Canadian geologists are accustomed to employ it — in a petrographical and structural sense — for crystalline gneisses and granites underlying the Huronian, although it is evident that these rocks have consolidated at a time later than the Huronian.

As described by Lawson, the Laurentian (Lower Archean) "occurs in large isolated central areas, more or less completely surrounded by the schists of the upper Archean, the encircling belts anastomosing and forming a continuous mesh work." It consists chiefly of a coarse reddish, often porphyritic rock, usually granite in the central part of the area, but showing a foliation, generally parallel to the periphery, where it comes in contact with the Huronian.

Throughout the region the Laurentian is in eruptive contact with the Huronian, and nowhere is a basal conglomerate of the Huronian found. Near the contact with the Huronian, strips and fragments of the Huronian are embedded in the gneiss; also dikes of granite, pegmatite or felsite generally run from the gneiss into the Huronian. The larger areas of gneiss and granite are evidently batholites. Some of the smaller granite bosses may be stumps of old volcanoes. The Huronian schists usually dip rather steeply away from the gneiss, at an angle seldom less than 45°. Finer-grained granites cut both the Keewatin and the Laurentian. However, it is not easy to say whether a given granite is Laurentian or a later granite.

It is believed that as a result of the piling up of a thickness of eight or ten miles of sediments and eruptive materials, represented by the Keewatin and Couchiching rocks, the slowly rising isogeotherms softened or fused the foundation, which rose into domes, the inner parts solidifying as granite, and the outer, more viscid portions having their constituents dragged into rough parallelism with the adjoining solid rocks and forming gneiss.

As the Huronian rocks south of Lake Superior and in New Brunswick are described by Van Hise and Dawson as presenting basal conglomerates resting unconformably on the Laurentian, it is suggested that in these cases the thickness of the sediments was not great enough to depress the Laurentian floor to the level of fusion or plasticity; or, that the Huronian, as recognized in these regions, is really younger and overlies the upturned edges of the rocks described as Huronian in the northern Archean.

Comments.— The above discussion is based on the most thorough field work yet done in this area, and the account probably marks an advance in the interpretation of the pre-Cambrian stratigraphy of the area northwest of Lake Superior, although the conclusions cannot yet be accepted as final. Some of the conclusions differ from those of other workers in this area, and such may be especially noted.

The Couchiching is believed to be entirely a sedimentary series, conformably below the Keewatin, and in eruptive contact with the Laurentian granite and gneiss below. Lawson regarded the Couchiching as sedimentary, but believed that there was an unconformity between it and the Keewatin, because of the great differences in the characters of the materials, the degree of crystallization, and the presence of basal conglomerates in places at the base of the Keewatin. Coleman has previously accepted these conclusions. Van Hise, accepting Lawson's conclusion as to the position of the Couchiching below the Keewatin, supposed the Couchiching to belong to the Basement Complex or Archean. However, recent personal work in the field has led him to the conclusion that the Couchiching of Rainy Lake is largely a sedimentary series, which is equivalent in age to the upper part of the series mapped by Lawson as Keewatin in the same area.

The insistence on the eruptive contact of all the rocks of the Laurentian with the Huronian and the explanation of the origin of the Laurentian may also be noted. Coleman believes that the gneisses and granites of the Fundamental Complex do not represent the earth's *erstarrungskruste*, but are portions of the earth's crust, of sedimentary or other origin, which have been buried deeply enough for hydrothermal fusion, and have afterwards been disinterred by long-continued denudation. After fusion of course such rocks would be really eruptive and of later age than the Huronian rocks above, even though originally they may have been older than them and formed the floor upon which the Huronian rocks were deposited. This is essentially the position of Lawson. Van Hise, on the other hand, believes that here the granites and gneisses heretofore included under the Laurentian of this region may be separated into (1) a granite-gneiss basal complex, forming the basement upon which the Huronian was deposited, and perhaps representing a portion of the original crust of the earth or its downward continuation, and (2) later granite and gneiss intrusive in the Huronian, and therefore of Huronian or post-Huronian age. This discrimination has been uniformly made south of Lake Superior, in a number of cases in Canada, and in other parts of North America, and it is believed that it may also be made in this region of western Ontario. If this were done the rocks of the true fundamental complex in this area would occupy perhaps a very small area. Whether such a complex may be called Archean, as advocated by the United States geologists, or by some other name, is immaterial. If the term Laurentian be employed, it would need to be redefined to cover the narrower range of rocks, and because of its present wide application, including both the basal complex and later eruptives, some confusion might result. The term Archean has been carefully defined and consistently used by the United States geologists to represent the oldest group of rocks or basal complex, and in this narrow application has priority to any other term.

The portion of the granites and gneiss intrusive in the Huronian would be called simply Huronian or post-Huronian. If the true basal complex be altogether absent in this region, the granites and gneisses now called Laurentian are of Huronian or post-Huronian age, and are not to be correlated with rocks of the true basal complex of other areas.

Parks[1] describes the geology of the base and meridian lines in the Rainy River district, in an area extending from Lac Seul on the northwest and Lake Wabigoon on the southwest, to Sturgeon Lake and Mattawa Lake on the east. Laurentian and Huronian rocks occur in folds with a general northeast-southwest trend. The Huronian rocks occur in three main areas, the Sturgeon River area, the Lake Minnetakie area, and the Wabigoon Lake area. They consist of altered traps, hornblende-schists and other green schists, altered porphyrites, quartz porphyries, phyllites, and conglomerates. In general they resemble Lawson's Keewatin series to the south. The Laurentian consists of hornblende-syenite, hornblende-granite-gneiss, mica-syenite, biotite-granite-gneiss, and various granitic rocks. C. K. LEITH.

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[1] Geology of base and meridian lines in the Rainy River district, by W. A. PARKS: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 161–183. With geological map.